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REPORTS

RESULTS OF THE ENTOMOLOGICAL ASPECTS

OF THE 1963 WESTERN HEMLOCK LOOPER CONTROL PROJECT

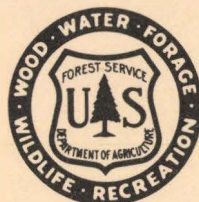
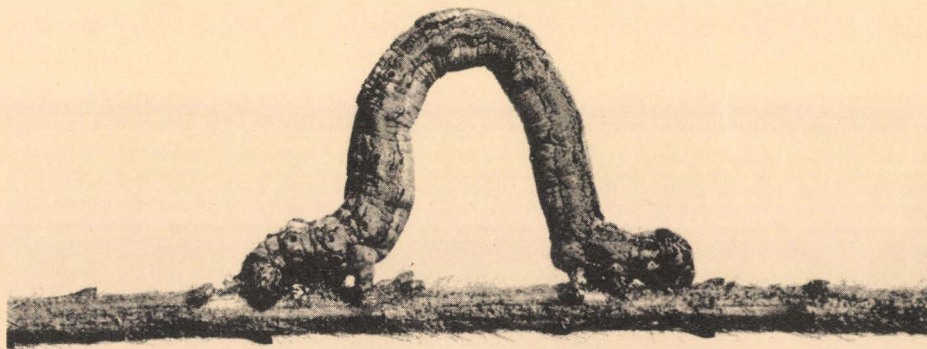
In Southwest Washington

INTERMOUNTAIN STATION
Central Reference File

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by

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INSECT AND DISEASE CONTROL BRANCH
DIVISION OF TIMBER MANAGEMENT
PACIFIC NORTHWEST REGION
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

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RESEARCH
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SUMMARY

In July 1963, 55,000 acres of a 70,000-acre western hemlock looper infestation in southwest Washington were treated with aerial applications of either Sevin or DDT. Sevin was applied to 43,000 acres and DDT to 12,000 acres by helicopter. This control project was administered by the State of Washington Department of Natural Resources. The U. S. Forest Service furnished technical assistance and guidance.

The technical staff consisted of U. S. Forest Service and Washington State Department of Natural Resources personnel and was headed by a Forest Service Entomologist. The main duties of the technical crew were to determine: spray initiation dates; spray coverage and deposit; and spray-caused looper mortality.

On June 25, results of continuous studies on larval development by the Project Entomologist indicated that most looper larvae would be in the second instar by July 5, so spraying could begin on that date, weather permitting.

Treatment began on July 5, as scheduled, and continued through July 24. Spray coverage was very good in DDT-treated areas and variable in Sevin-treated areas. Spray distribution from the tops of trees to the ground was excellent.

Weather was poor during much of the treatment period with frequent rain and high winds. Precipitation measurements were taken at several stations from July 13 through August 1 and averaged 1.65 inches.

Looper larval mortality was sampled at 19 plots--18 in the Sevin area and 1 in the DDT area. Mortality was poor and variable for Sevin and excellent for DDT. Larval kill on the 18 Sevin plots averaged 20 percent and ranged from 0 to 86 percent. Looper mortality on the one DDT plot was 98 percent. Sevin-caused mortality was insufficient to prevent tree mortality in areas with heavy looper populations. The reason for variability in Sevin-caused mortality is unknown, but kill was not directly related to spray deposit.

Recommendations are made for future project use.

INTRODUCTION

The western hemlock looper, Lambdina fiscellaria var. lugubrosa Hulst, is a periodic pest in western hemlock stands along the coasts of British Columbia, Washington and Oregon. The first known serious outbreak in Oregon and Washington was detected in 1889. Since then, four or five major and several minor outbreaks have occurred (10). In 1961, looper damage was discovered in northwest Oregon, and entomologists predicted that an epidemic looper infestation would possibly build up in southwest Washington in 1962 or 1963.

A limited survey was made in the winter of 1961-62 to sample overwintering looper egg populations. Results were variable. In the fall of 1962, looper damage was detected on 6,000 acres in Pacific County, Washington (13). A cooperative survey to detect looper eggs was made in the winter of 1962-63 by Industry, Washington State Department of Natural Resources and the U. S. Forest Service in Grays Harbor, Pacific and Wahkiakum Counties. Results of the survey showed that looper egg populations were abundant in hemlock stands in Pacific and Wahkiakum Counties and that subsequent larval populations would probably cause wholesale damage in 1963 (4). Using data from the egg survey and from aerial photos taken in March 1963, representatives of Industry, the State Department of Natural Resources, and the U. S. Forest Service delineated a 70,000-acre hazard area in Pacific and Wahkiakum Counties. Information regarding the outbreak was then presented to the Northwest Forest Pest Action Council. The Council recommended that the area be sprayed using precautions adequate to protect other resources.

Three past looper outbreaks have been controlled by aerial application of chemicals. In 1931, 6,000 acres were treated in Pacific County, Washington by fixed-wing aircraft with 20 lbs. of calcium arsenate dust per acre at a cost of \$2.71 per acre (15). An 11,600-acre infestation in Clatsop County, Oregon, was sprayed with two different insecticides, an aqueous suspension of lead arsenate and an oil emulsion of DDT in 1945 by fixed-wing aircraft. Lead arsenate was used on 9,300 acres at the rate of 10 lbs. in 4-1/2 gallons of liquid per acre at a cost of \$3.50 per acre. DDT was sprayed on 2,300 acres at the rate of 1 lb. in 2 gallons of fuel oil per acre at a cost of \$2.35 per acre (12). In 1962, a 33,000-acre infestation in Clatsop County was treated with 1/2 lb. of DDT in 1-1/2 gallons of fuel oil per acre applied by fixed-wing aircraft at a cost of \$1.43 per acre (5).

The primary purpose of a western hemlock looper spray project is to reduce looper populations below the tree killing level. Generally, an outbreak is brought under control by natural factors, mainly a virus disease, after three or four years of activity. However, natural control does not take place until the late stages of larval development. By this time, most of the larval feeding is over and tremendous damage has occurred.

DDT at 3/4 lb. per acre was recommended for use on the 1963 southwest Washington project. DDT was advocated because it is relatively cheap, easy to apply, and the only insecticide known to be effective against looper larvae. Previous spray projects in Clatsop County, Oregon showed that 1/2 lb. per acre was insufficient and that slightly less than 1 lb. per acre was probably adequate for control. A dosage rate of 3/4 lb. was recommended because the Forest Service wanted to use the smallest amount of insecticide that would give sufficient control.

To insure good control over application and to reduce the likelihood of drift and its subsequent detrimental effects on other resources, U. S. Forest Service personnel recommended that helicopters be used to apply the insecticide. By flying at an average air speed of 30 m.p.h. at a height of 30 feet above the tree tops using swath widths of 60-75 feet, helicopters could avoid direct deposit upon and excessive drift from reaching critical spawning streams, watersheds, reservoirs, inlets, bays, pastures, fish hatcheries, and residences. The U. S. Forest Service also recommended testing the carbamate Sevin, the organic phosphate Phosphamidon, and the biological agent Bacillus thuringiensis against the looper in an effort to obtain a satisfactory substitute for DDT for future looper control projects.

These recommendations were presented to the Federal Pest Control Review Board in Washington, D. C. in the early spring of 1963. The Review Board approved use of DDT on areas with streams draining into the Columbia River. However, the Board rejected the use of DDT on areas with streams draining into Willapa Bay because of potential danger to oysters. Past studies indicated that oysters accumulate DDT at a rapid rate. Also, the oyster industry strongly objected to the project. A new proposal was submitted to the Board recommending the use of Sevin in the Willapa Bay drainages. This proposal was accepted and Federal participation approved. Testing of other direct control methods was also approved.

In December 1962, representatives of the U. S. Forest Service and the State Department of Natural Resources contacted state and federal agencies to organize a cooperative team to study the effects of insecticides on other organisms in the proposed spray area. As a result, a committee was formed under the chairmanship

of the Washington State Pollution Control Commission. The monitoring committee included representatives of the following private companies and state and federal agencies:

Private Companies

Weyerhaeuser Company
Crown Zellerbach Corporation
Rayonier, Incorporated

State of Oregon Agencies

Sanitary Authority

State of Washington Agencies

Pollution Control Commission
Department of Health
Department of Fisheries
Department of Game
Department of Agriculture
Department of Conservation
Department of Natural Resources

Federal Agencies

Public Health Service
Food and Drug Administration
Fish and Wildlife Service
 Bureau of Sports Fisheries and Wildlife
 Bureau of Commercial Fisheries
Agricultural Research Service
Forest Service

The study committee outlined and organized a program to study the effects of spraying on water quality, fresh and salt water organisms and terrestrial organisms. Studies were begun before spraying commenced and continued through the application of the insecticides. Post-spray analyses will not be completed for at least one year. Results of these studies will be reported in a joint study committee release.

This report spells out activities of the technical staff during the operational spray program. Results of the pilot tests are reported separately (6).

THE OPERATIONAL PROGRAM

The Willapa Looper Control Project was administered by the Washington State Department of Natural Resources. G. R. Little, Supervisor, Inventory Section, Forest Management Division, Olympia, was appointed Project Director. D. R. Hopkins, Supervisor, Forest Management Division, had the administrative responsibility for the overall direction of the project. Technical aspects of the project were directed by P. E. Buffam, Entomologist, Insect and Disease Control Branch, Division of Timber Management, Regional Office, U. S. Forest Service, Portland, Oregon. C. R. Fink, Forester, Insect and Disease Control Branch, furnished liaison for the entire project and was responsible for direction of the operational phases of the pilot testing. Benton Howard, Chief, Insect and Disease Control Branch, served as a consultant.

The 70,000-acre control area was divided into 41 blocks to coincide with helispots established in or adjacent to the control area (fig. 1). Blocks ranged in size from 144 to 4,141 acres (table 1). Maximum unit spraying distance from a helispot was 2-1/2 miles.

During the portion of the operational project administered by the Department of Natural Resources, 55,000 acres of the original 70,000 acres were sprayed. This figure includes 5,016 acres sprayed during the Sevin and DDT pilot tests. Block 15 was eliminated because of a very low looper population. During the pilot tests, 2,276 acres were treated with Phosphamidon and 325 acres with Bacillus thuringiensis. The remaining acreage deleted was in the Bear River Ridge and North Nemah River-Williams Creek areas--areas that harbored heavy looper populations and were relatively inaccessible. When data showed that Sevin was inadequately controlling heavy looper populations, these areas were withheld from treatment. Weyerhaeuser Company and Crown Zellerbach Corporation sprayed these areas with DDT after the State-administered project was completed (9).

Most of the area sprayed during the operational program was privately owned (table 2). Weyerhaeuser Company and Crown Zellerbach Corporation were the principal landowners.

Figure 1.--Project Entomologist pointing out block delineations on Project map.

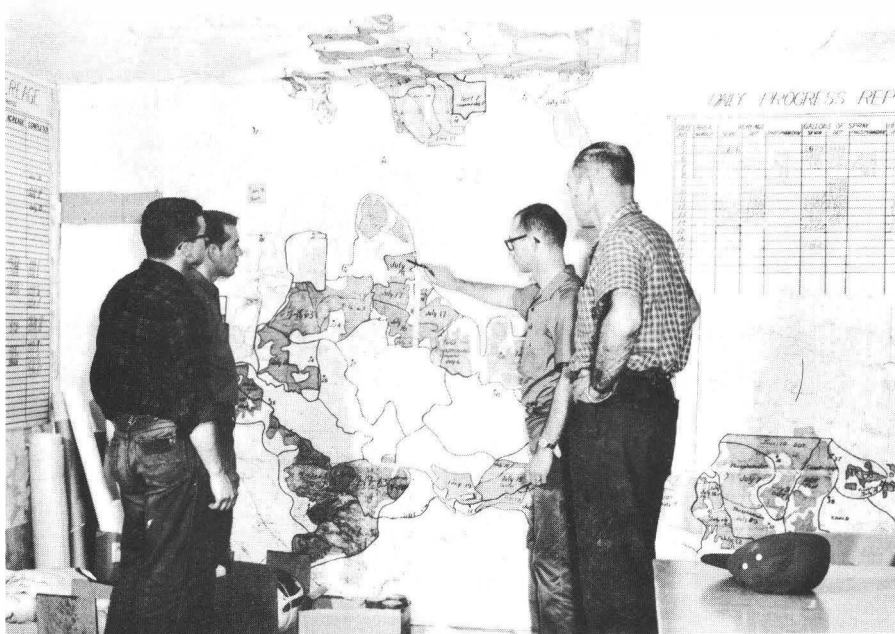
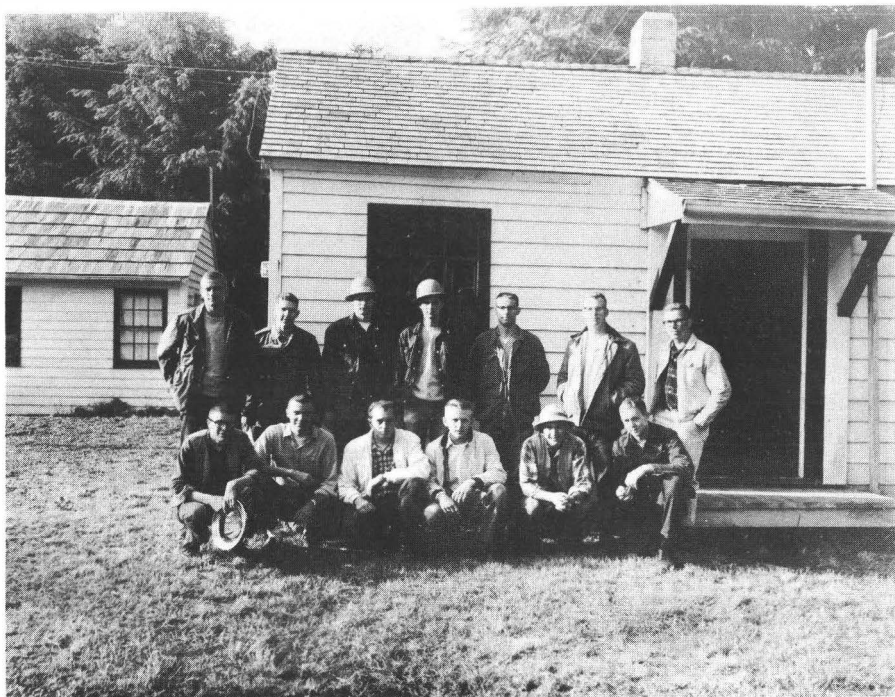


Figure 2.--1963 Southwest Washington Hemlock Looper Control Project technical staff.



First row, left to right: D. Dickman, J. Caffrey, **M. Headings**, D. Dokken, R. Carlson, G. Cochran. Second row, left to right: T. Hazelrigg, W. Suydam, J. Hudson, G. Ikerd, L. Millam, S. Karr, D. Miller.

Table 1.--Block release and spray dates by treatment during the 1963

Western Hemlock Looper Control Project in southwest Washington

Treatment	:Block No.:	Acreage	:July spray: July : release : spray : date(s) : date(s)
<u>Bacillus thuringiensis</u>			
(Pilot Test)	18	<u>325</u>	19 19
	Subtotal	<u>325</u>	
Phosphamidon			
(Pilot Test)	28	441	6 6
	39	<u>1,835</u>	6 6-9
	Subtotal	<u>2,276</u>	
DDT (Pilot Test)	38	<u>1,125</u>	5 5,6
	Subtotal	<u>1,125</u>	
DDT (Operational)	25	748	7 7,9
	31	1,211	7 9,11,12
	32	841	7 9,11,13
	34	1,857	7 9,10
	35	1,770	7 10-14
	36	1,465	7 9,10
	37	144	7 14
	40	1,246	7 10-14
	41	<u>1,783</u>	7 7,9,10
	Subtotal	<u>11,065</u>	
Sevin (Pilot Test)	14	1,203	5 5
	28	1,690	5 5-7
	29	<u>998</u>	5 5,6
	Subtotal	<u>3,891</u>	

Table 1.--Block release and spray dates by treatment during the 1963

Western Hemlock Looper Control Project in southwest Washington

(Continued)

Treatment	:Block No.:	Acreage	:July spray: : release : : date(s) :	July spray date(s)
Sevin (Operational)	2	1,181	13	16-19
	3	2,211	16	17,18
	4	2,575	11	12,13,18-20
	5	4,141	11,16	13,15-18
	7	2,117	17	17-23
	8	2,687	11	11-16
	9	2,163	12	16,17,22,23
	11	2,098	11	11-13,15,16
	12	1,781	11	15-17
	13	1,901	11	11,12
	14	1,509	11	13-15,17
	16	1,828	16	17-20
	19	881	16	19
	20	1,920	13	15-18
	21	2,092	13	16-18
	23	768	11	12,14,15
	24	890	13	16,17
	25	263	13	15,16
	26	394	13	20
	27	782	13	18-20,22,23
	30	1,172	17	20,22,23
	33	965	12	13-15,19
	34	2,153	13	15-17
	35	447	13	13,14
Subtotal		38,919		
Total		<u>57,601</u>		

Table 2.--Land ownership on areas treated with Sevin and DDT during
the operational phase of the 1963 Looper Project.

Land owner	Treatment area by insecticide used		Total	Percent of total acre- age sprayed
	Sevin	DDT		
	<u>Acres</u>	<u>Acres</u>	<u>Acres</u>	
Weyerhaeuser Co.	23,160	2,041	25,201	45.8
Crown Zellerbach Corporation	8,910	6,994	15,904	28.9
Rayonier Inc.	3,127	0	3,127	5.7
Small Private	5,094	1,421	6,515	11.9
State	2,855	888	3,743	6.8
Federal	58	452	510	0.9
Totals	43,204	11,796	55,000	100.0

Sevin, at the rate of 1.6 lbs. of active ingredient in 1-1/2 gallons of water per acre, was used on 79 percent of the total area treated during the operational project. DDT was applied on the remaining 21 percent at the rate of 3/4 lb. of active ingredient in 1-1/2 gallons of solvent and #2 fuel oil per acre. Cost per acre using Sevin was \$3.16 and with DDT \$2.56.

THE ENTOMOLOGICAL PROGRAM

Technical personnel were responsible for three major phases of the looper control project:

1. Determine the time to spray each block.
2. Determine spray coverage and deposit.
3. Determine spray-caused looper mortality.

A crew of six U. S. Forest Service and eight Washington State Department of Natural Resources personnel were assigned to the technical staff to accomplish these objectives (fig. 2). The technical staff was also responsible for monitoring the Phosphamidon and Sevin pilot tests and assisting Pacific Northwest Forest and Range Experiment Station personnel on the Bacillus thuringiensis test.

U. S. Forest Service personnel reported to Project Headquarters at Naselle, Washington on June 10. Technical staff members from the Department of Natural Resources reported the following day. Personnel comprising the technical staff are listed below. Duties of the Project Entomologist, Entomological Assistants and Insect Checkers have been previously reported (3).

<u>Project Entomologist</u>	-	P. E. Buffam, U.S.F.S.
<u>Entomological Assistants</u>	-	D. L. Miller, U.S.F.S.
		M. E. Headings, U.S.F.S.

Insect Checkers -

R. L. Carlson, U.S.F.S.	J. Hudson, W.S.D.N.R.
G. E. Cochran, U.S.F.S.	G. Ikerd, W.S.D.N.R.
D. A. Dokken, U.S.F.S.	S. Karr, W.S.D.N.R.
J. Caffrey, W.S.D.N.R.	L. Millam, W.S.D.N.R.
D. Dickman, W.S.D.N.R.	W. Suydam, W.S.D.N.R.
T. Hazelrigg, W.S.D.N.R.	

Time spent by technical personnel on the cooperative project and the different pilot tests is summarized in table 3. Seventy percent of the work was on cooperative project activities. The remaining time was divided among the three pilot tests.

Table 3.--Time spent on western hemlock looper control project technical activities by State Department of Natural Resources and U. S. Forest Service personnel

Activity	:Time in man-days worked by project personnel		
	: State Department	:	:
	: of Natural Resources	: U.S.F.S.	: Total
Cooperative Project	190	215	405
Phosphamidon Pilot Test	57	37	94
Sevin Pilot Test	38	35	73
<u>Bacillus thuringiensis</u>			
Pilot Test	-	3	3
Total	285	290	575

Release of Spray Blocks

To effectively control the western hemlock looper, the pesticide should be applied when looper larvae are in an early stage of development and after all viable eggs have hatched. This period of time is thought to be when most of the larvae are in the second instar and when no very small first instars can be found.

Periodic larval samples were taken at various points within the control project area to determine larval development. Looper larvae were collected from both understory and overstory foliage (fig. 3). At each collection point, specimens were placed in alcohol-filled vials according to collecting site. In the laboratory at Project Headquarters larvae were separated into stage of development by head capsule width measurements using a binocular microscope.

Larval development was determined from collections made between June 11 and August 2. Figure 4 shows the buildup, peak occurrence, and decline of each larval instar by dates during the collection period. At least 50% of the eggs had hatched at the time sampling was begun. A 10-day advance notice to begin spraying was submitted by the Project Entomologist to the Project Director on June 25. The notice stated that spraying should begin on July 5. The Sevin and DDT pilot test areas were to be sprayed first and the Phosphamidon pilot test areas second. After these areas were treated, all spray blocks designated for DDT treatment in the cooperative project area would be treated. Blocks to be sprayed with Sevin were last on the priority list.

Larval development was not significantly different between blocks. However, development was slightly slower in some of the blocks north of the North Nemah River Road, due at least partially to elevational differences. These blocks were not released for spraying until the latter part of the project (table 1). Some block boundaries were altered during the project resulting in some block grouping. Portions of a few blocks were never released for Sevin spraying because they contained heavy looper populations. These areas were treated with DDT by the private companies upon completion of the State-administered project.

Figure 3.--Collecting looper larvae from an understory
vine maple using a 3-foot-square muslin beating sheet.



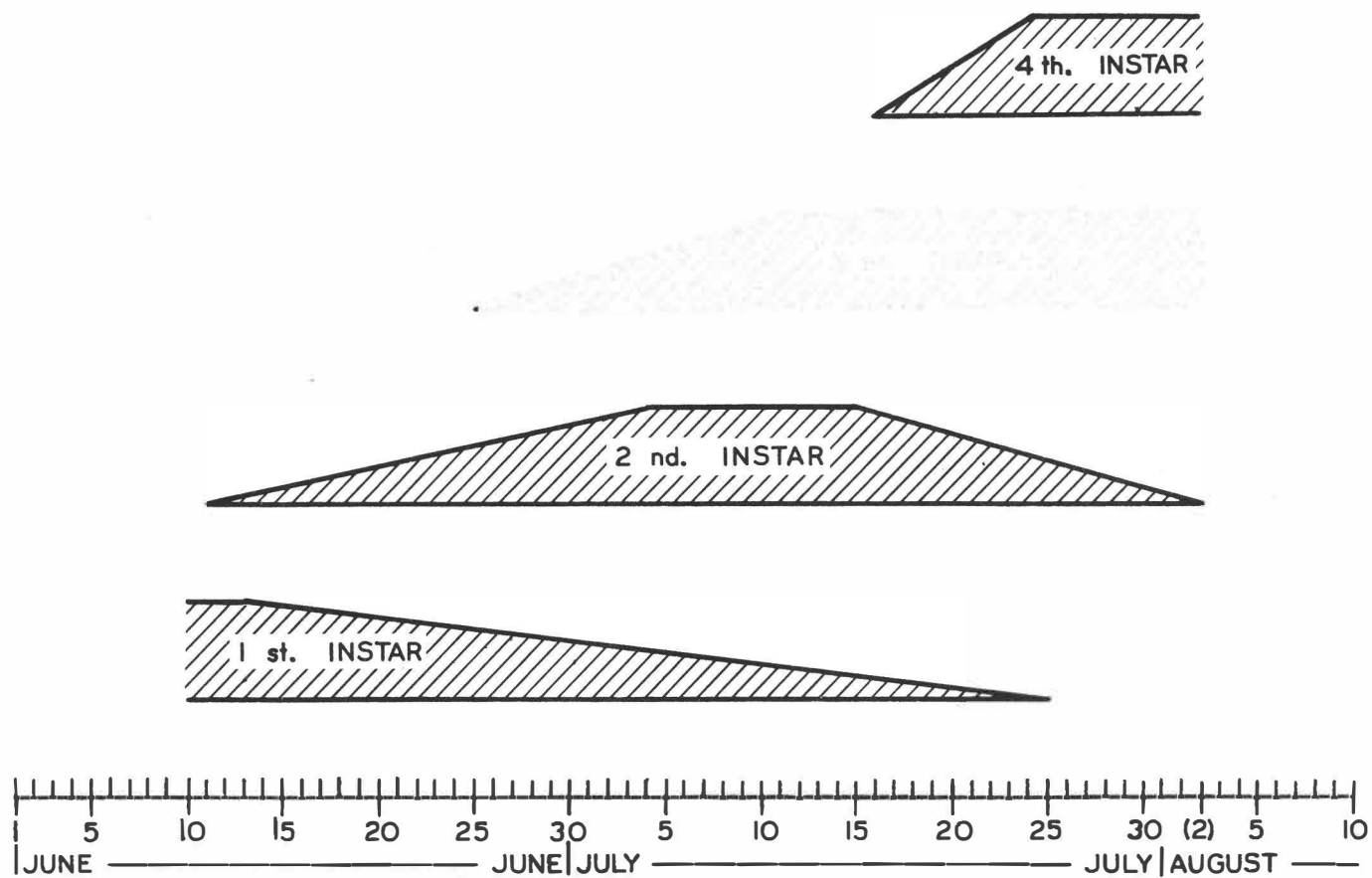


Figure 4.--Western hemlock looper larval development in southwest Washington from June 10 to August 2, 1963.

Spray Coverage and Deposit

Spraying began on July 5 and continued through July 24 (tables 1 and 4). Periods of heavy rain were encountered during this time, thus greatly decreasing optimum flying conditions. Temperature extremes did not directly limit spraying, but excessive winds and moisture did. As many as nine helispots were manned in a single day to capitalize on satisfactory localized spray conditions.

Table 4.--Area sprayed by dates during the July 1963 Western Hemlock Looper Spray Project in southwest Washington

Date	Area sprayed	Date	Area sprayed
	<u>Acres</u>		<u>Acres</u>
5	3,266	15	4,230
6	1,847	16	5,771
7	3,041	17	8,432
8	44	18	2,959
9	2,009	19	3,331
10	2,433	20	1,533
11	4,170	21	0
12	5,691	22	823
13	2,728	23	<u>2,862</u>
14	2,431	Total	57,601 ^{1/}

^{1/} Includes 2,601 acres sprayed with Phosphamidon and Bacillus thuringiensis during the pilot tests.

Spray cards were distributed at mortality sampling points within the project area to determine the intensity and distribution of spray reaching the forest floor. Some cards were distributed in pastures and others in or near streams to determine possible drift patterns (fig. 5). Black 5" x 7" cards made from 25½" x 30½" index card stock (1,000 sheets weigh 220 lbs.) were used to detect Sevin (fig. 6). Sevin appeared as white or cream-colored spots on the cards. Oil-sensitive spray deposit cards were used in the DDT treated area (fig. 6). Both types of spray cards were placed in holders made of 14-gauge galvanized wire (11). Holders kept the cards above the brush and prevented curling.

Figure 5.--Placing spray deposit cards on a gravel bar in the middle of the North Nemah River.



Figure 6.--Examining three types of spray cards in wire holders. Left to right 5" x 7" filter paper; 5" x 7" black card; 4" x 5" oil sensitive card.



Some 200 cards were placed in the DDT pilot test areas, and these were considered sufficient to rate spray coverage and deposit for the entire DDT-treated area. Oil-sensitive cards were compared with Davis' (8) standards and the amount of DDT per acre estimated. No exact standards have been established for Sevin, so spray intensity was estimated for each card and was categorized as follows: None, light, moderate, or heavy.

Spray coverage was good in the DDT areas and variable in the Sevin areas (table 5). All plots in the DDT pilot test area and the one plot in the operational area were sprayed satisfactorily. Sevin coverage was good on 11 of the 18 mortality plots. However, plots 7A, 7B, 11B, and 11D in the Sevin area were not treated satisfactorily. The only spray reaching the plot trees probably resulted from drift. A daily estimate of spray coverage was submitted to the Project Director stating that these plots had not been sprayed satisfactorily, but the plot areas were not resprayed. Plots 11B and 11D were about 1/4 mile from the North Nemah River. The spray pilots had been told to control drift near the North Nemah River, so they probably intentionally stayed back from the spray boundary to prevent any contamination of this important salmon spawning stream. Spray intensity on plots 12A, 21A, and 33A was marginal.

No spray was detected on the cards placed in pastures adjacent to the Jim Crow Creek area. Some very light Sevin drift was recovered on the cards placed in the North Nemah River. Forage and water samples were collected at these two locations, respectively. Chemical analyses of these materials will be reported by the monitoring committee.

Vertical spray coverage with helicopters was excellent. The amount of spray reaching the lower crowns and understory was more than that obtained with fixed-wing aircraft on the 1962 Clatsop County, Oregon Western Hemlock Looper Control Project. Vertical penetration is very important because looper larvae are distributed throughout the crowns of standing trees and the understory plants as well.

The black cards were satisfactory to determine spray coverage of Sevin. Also, white spots of Sevin could be easily detected on almost all types of green foliage, rotten logs, old stump tops, bark, etc. However, a method of estimating actual spray deposits reaching the cards is needed. Actual deposits of Sevin were measured in the Sevin pilot test area using filter papers that were analyzed by Agricultural Research Service, U.S.D.A., Yakima, Washington (2) (fig.6). This method is too expensive for widespread use on a project, and results cannot be obtained immediately.

Table 5.--Larval mortality by spray coverage class on the 1963 southwest Washington Western Hemlock Looper Control Project mortality plots

Estimated spray:	:	:	Control:	Pre-spray:	Post-spray:	:	
coverage	:	:	Mortality:	block	larval	larval	Percent
on plot	:	Treatment:	plot no.	no.	count	count	mortality ^{1/}
Very light	Sevin	7A	7	60	36	32.0	
		11B	11	254	178	23.8	
		11D	11	291	249	7.0	
Light	Sevin	7B	7	18	11	30.8	
		7F	7	42	15	59.6	
Light-Moderate	Sevin	12A	12	23	7	67.6	
		21A	21	21	8	59.3	
		33A	33	7	6	8.6	
Moderate	Sevin	3A	3	8	7	3.3	
		9A	9	50	19	57.3	
		9B	9	42	45	0.0	
		11C	11	122	119	2.5	
		20A	20	21	10	49.1	
		20B	20	38	14	60.7	
Heavy	Sevin	8A	8	52	38	18.8	
		11A	11	122	46	59.0	
		20C	20	76	10	85.9	
		23A	23	17	18	0.0	
Totals				1,264	836	Wtd. 19.62 Av.	
Moderate-Heavy	DDT	39A	39	47	1	97.9	

^{1/} Sevin figures corrected for natural mortality by Abbott's (1) formula from data furnished by V. M. Carolin, Forest Insect Research, PNW Forest and Range Experiment Station:

$$\frac{x-y}{x} \times 100 = \% \text{ Control.}$$

x = % Survival in control larvae.

y = % Survival in treated larvae.

Weather

During the first 10 days of spray application, precipitation and generally inclement weather prevailed. Some storms resulted in near-torrential downpours of rain that could have washed insecticides from tree foliage, thus causing a reduction of looper larval mortality. However, technical personnel noted large amounts of Sevin on tree foliage after several of these downpours.

Improvised rain gauges were installed at five different collection points in the North Nemah River area to determine the variability of precipitation between areas in the same drainage. Measurements were taken periodically from July 13 through July 31. Total precipitation at each of these five plots was relatively similar (table 6).

Table 6.--Precipitation records based on rain gauges installed at several locations in the North Nemah River area during the 1963 Western Hemlock Looper Control Project in southwest Washington

Date of collection :	Precipitation in inches by collection point				
	11A	11D	12A	13A	13 B&C
7-13 a.m.	Trace	Trace	Trace	Trace	Trace
p.m.	*	0.10	*	*	*
7-14	*	0.13	0.10	0.10	0.11
7-15	0.26	0.05	*	*	*
7-16	0.00	0.00	Trace	Trace	0.10
7-17	0.00	0.00	0.00	0.00	0.00
7-18	0.00	0.00	0.00	0.00	0.00
7-19	0.00	0.00	0.00	0.00	0.00
7-20	0.00	0.00	0.00	0.00	0.00
7-21	*	*	*	*	*
7-22	1.20	1.30+	1.20	1.40+	1.20+
7-23	0.00	0.00	0.00	0.00	0.00
7-24	Trace	Trace	0.00	0.00	0.00
7-25	0.00	0.00	0.00	0.00	0.00
7-29	0.00	0.00	0.00	0.00	0.00
7-30	Trace	Trace	Trace	Trace	Trace
7-31	0.20	0.20	0.20	0.20	0.20
Total precip.	1.66	1.78	1.50	1.70	1.61

* Precipitation not measured on this date.

Larval Mortality Sampling

Pre-and post-spray larval samples were taken at 19 points within the control area to determine results of insecticidal treatment. Originally, 28 mortality plots were established, but 9 of these were used during small-scale tests of Sevin in several carriers, spreaders and stickers and at different dosage rates. Of the 19 plots sampled, 18 were in the Sevin-treated area and one in the DDT-treated area. No time was available between the pilot testing and the operational DDT-spraying to establish and rate more than one plot in the DDT area. Data from the 20 DDT pilot test plots in the Jim Crow Creek area would provide additional information on the results of the DDT treatment. The original plan was to establish one mortality plot in each spray block. However, some blocks were either totally or partially inaccessible and could not be sampled in the allotted time. Most of the unsampled blocks were in the Bear River Ridge area. As a result, several plots were established in each accessible and heavily infested block (table 5).

At each mortality plot, five codominant and/or intermediate western hemlock trees with lower crowns within 10-35 feet of the ground were selected and designated as plot trees. Trees were sampled immediately before the plot was sprayed and at periodic intervals thereafter. The sample consisted of five 18-inch branches clipped from each plot tree, using aluminum pole pruners (fig. 7). Branches were caught in a basket attached to the pole immediately below the pruning head. Then the branches were lowered to the ground and shaken over a muslin drop cloth (fig. 8). Number of looper larvae on the drop cloth was counted and recorded. The percent of larval survival between the pre-spray larval count and the count taken 10 days after spraying in the Sevin areas was calculated for each plot using Abbott's (1) formula. Natural mortality figures for the Sevin-treated plots were supplied by V. M. Carolin, Entomologist, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, from data taken on a check plot on Long Island in Willapa Bay from July 12 through August 20. Larval mortality on plots in a non-sprayed check area in the Jim Crow Creek drainage for the July 5-31 period was high (68 percent). Spray analysis results from filter papers left in the area indicated that DDT spray drift had reached some plot trees. This drift undoubtedly accounted, at least in part, for the high mortality on the plots. Therefore, mortality figures from these plots were not considered to be indicative of the true natural mortality, so they were deleted. However, past records indicate that natural mortality was probably low during this period. The method for computing larval mortality for plot 39A which was in the Jim Crow Creek area was previously reported (3).

Figure 7.--Sampling looper larval mortality using an aluminum pole pruner.



Figure 8.--Shaking twigs cut with a pole pruner over a muslin sheet to dislodge looper larvae.



Results of the treatment during the operational project were poor with Sevin and excellent with DDT. Sevin-caused mortality on 18 plots ranged from 0.0 to 85.9 percent and averaged 19.6 percent (table 5). Larval mortality on the one DDT-sprayed plot was 97.9 percent. To prevent tree mortality, chemical and natural controls must cause a combined larval mortality in excess of 88 percent in areas with heavy looper populations during the ten day period following treatment (5). Therefore, treatment in 1963 with DDT was considered adequate and with Sevin inadequate to prevent serious damage where looper populations were great.

The reasons for the variability in mortality obtained on the 18 plots sprayed with Sevin are unknown. Larval mortality, however, was not directly related to estimated spray deposit ($r=0.17$). Plots 9B and 23A were moderately to heavily treated, but no mortality was obtained. Plots 7A and 11B received very light concentrations of spray, but looper mortality was 32 and 24 percent, respectively. One or more of the following factors may have attributed to the variability:

1. Each batch of insecticide may not have contained the same amount of active ingredient. Batches of Sevin were mixed at a central mixing plant in Naselle by inexperienced personnel. Possibly the ratio of Sevin wettable powder to water was not the same in all cases. Also, the first few batches settled to the bottom of the mixing tank. However, a circulation system was developed to alleviate this situation. Occasionally, samples were taken of the mixture and sent to the Washington State Department of Agriculture for analysis. A sample collected on July 4 contained 0.8615 lbs. of actual Sevin per gallon instead of the required 1.06 lbs. per gallon.^{1/}
2. Each helicopter load from the same nurse tanker may not have contained the same amount of active ingredient. Mixed insecticide occasionally was stored at a helispot overnight and might have been loaded into a helicopter the next day without sufficient agitation to insure that material was in suspension. After it was discovered that Sevin settled to the bottom of the tanks, some agitation was required.

^{1/} Communication from the Washington State Department of Agriculture to the Washington State Pollution Control Commission.

3. Several different types of spray nozzles were used that probably produced different spray droplet sizes. Looper larvae may be able to detect large Sevin droplets on a hemlock leaf and bypass these droplets while feeding. Technical personnel reported that many living looper larvae were often found on foliage containing appreciable Sevin deposits.
4. Precipitation could have washed small droplets of the insecticide from the foliage. However, technical personnel noted several times that heavy deposits of Sevin were still noticeable on foliage after a heavy rainfall. Precipitation may occur in the coastal areas of Oregon and Washington during much of the time that a looper control program is in progress. Therefore, the insecticide chosen for the job must be effective during wet weather as well as dry weather.

Results of the 1963 cooperative aerial detection survey showed that 8,040 acres in southwest Washington were defoliated to some degree in 1963 compared with 5,990 acres in 1962 (14). This 2,000-acre increase occurred mainly in areas treated only with Sevin. However, some additional defoliation did occur in the Bear River Ridge area treated with DDT by Weyerhaeuser Company and Crown Zellerbach Corporation. Trees in areas sprayed towards the latter part of July might have been defoliated before the spray was applied.

In December 1963 and January 1964, a survey was made in western Washington to sample overwintering hemlock looper egg populations. Results of the egg survey indicate that looper populations in southwest Washington in 1964 will be low. Some localized defoliation might occur in an unsprayed area on Long Island, two areas on Bear River Ridge--one treated with Sevin and one with DDT (the latter by Weyerhaeuser Company and Crown Zellerbach Corporation after the State-administered program was completed)--and two Sevin-treated areas near the North Nemah River. More eggs were recovered in samples collected in Sevin-sprayed areas than DDT-sprayed areas. No eggs were collected in the Jim Crow Creek area (7).

Again on this project, DDT has shown its excellence in controlling outbreaks of forest defoliators. Sevin in the formulation used (80% sprayable) did not reduce looper larval populations to the desired level. This carbamate should not be used again against the looper, until its efficiency in killing all looper larval stages is proven in well-designed laboratory or small-scale field tests.

RECOMMENDATIONS

During the project, technical personnel suggested a few possible improvements of methods used by technical and operational crews. The recommended changes are listed below. Some were followed during the latter part of the Project, some should be used on future looper control projects, and some should be at least considered during future project planning sessions. Some suggestions for future research were also suggested.

Spray Cards

1. Spray deposit cards should be placed in openings at least 15 feet in diameter, if possible. Generally this was done, but in some cases placement could have been improved.
2. Spray deposit cards should not be removed until the area has been directly sprayed. Cards on some plots were collected before plot trees were directly hit and only drift was recorded. However, technical crews had no sure way to tell which areas had been directly treated. The Project Clerk was the only person consistently in the Project Office that knew much about spraying progress, but he seldom knew exactly what areas had been treated.

Each day spray pilots or helispot monitors should record the acreage sprayed on a map at Project Headquarters. This would prevent a great deal of back-tracking for the technical staff concerning card collections and a great deal of confusion for all involved. Spray pilots mapped their daily progress on the 1962 Looper Control Project in north-west Oregon to the benefit of both the Project Director and the Project Entomologist.

Technical Equipment

3. Pole pruners with aluminum telescoping sections not more than 5 feet long should be used. The two pole pruners purchased in 1963 for this Project had 6-foot-long sections and were cumbersome to assemble and their large diameter reduced operating efficiency.
4. Pre-made vial labels should be used to insure standardized collection of field data by each crew.

5. At least one 4-wheel-drive vehicle should be available for technical staff use. Several points within the Project area were almost inaccessible by 2-wheel-drive vehicles, especially during or immediately after rain.

Miscellaneous Technical Aspects

6. Larvae collected during pre-spray sampling should be preserved for later separation by larval instars to determine the larval stage treated. This will help determine whether larval mortality varies with stage of development treated.
7. The Project Entomologist should make up a work schedule for all technical personnel and post this schedule one or more days in advance, if possible. Posted work schedules prevent disorganization and loss of working time in the morning. Work schedules were posted in advance the latter part of the project and worked out very well.
8. The technical staff's office should be separated from the operational staff's office by at least a closeable door. Several times during the Project, technical equipment was borrowed without authority. Also, occasionally, people congregated in the technical staff's office to the extent that the entomologists had difficulty working.

Project Direction

9. At least one member of the Project Director's staff should be present at the Project Office at all times during working hours to answer the telephone and radio. At times, the Project Clerk left the office when only the entomologists were present. Over the telephone or radio, the entomologists were asked questions that they were unqualified to answer concerning administrative matters.
10. The Project Director should notify the Project Entomologist immediately of any changes in block boundaries, so that block releases can be made accordingly. Boundaries were changed and some blocks grouped during the 1963 Project. However, the Project Entomologist was not notified of the changes until he discovered boundary discrepancies between the original project maps and the one being used by the Project Director.

11. Each batch of insecticide should be tested to insure uniformity, and nurse tanker loads should be tested occasionally to determine if the insecticide is settling out.
12. During briefing sessions, pilots should not be indoctrinated to the extent that they are afraid to spray near a stream. Some mortality plots near streams were either lightly hit with drift or missed entirely. This happened because the pilots were apparently overcautious. In most cases, the streams were at least two swath widths (120-150 feet) from the plot. Helicopters should be able to spray fairly close to streams during wind-free periods without causing contamination. Spraying must be as close to streams as possible because many of the heavier looper populations are on trees near streams.

Research

13. Studies should be made of the effect of rain on the vertical distribution of looper larvae in the tree crown. Larvae may drop to the lower crown following a heavy rain. This could have a definite effect on sampling results, because larvae in the lower crown third are sampled for larval mortality. If more larvae are present because rain has dislodged them from above, then mortality percentages will be incorrect.
14. Studies should be made of larval mortality in the upper and mid-crown levels compared with that in the lower crown. More spray undoubtedly reaches the upper and mid-crown levels than the lower crown during aerial application, therefore, looper mortality should be greater at the latter two crown positions. However, distribution of larvae throughout the crown at the time of spraying is not known.

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